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Towards a Polarization Control of the Directional Scattering of Semiconductor Nanoparticles

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Abstract

The directional scattering, arising from the coherent interference of the electric and magnetic dipoles in dielectric nanoparticles, is a new step forward in the total control of light at the nanoscale [1]. In addition, it seems to be a useful phenomenon for a large variety of devices, such as all-optical circuitry elements [2]. In several cases, the active operation of these elements is required, thus an active control over the directional scattering may be necessary. This control may be achieved by shifting the resonant positions, i.e. by changing the size, shape or surrounding medium of the nanoparticle, or by changing the incident wavelength [3]. In all these cases, the directional condition is shifted and it is not satisfied under the initial conditions anymore. Unfortunately, these possibilities are not reversible or easy to implement in a real application. Despite this, the anisotropy of disk-shaped nanoparticles under a polarization change may be a promise solution.

In this work, we have studied the variation of the distribution of light scattering of dielectric nanodisks satisfying the directional conditions when the polarization of the incident beam is rotated from a TE to a TM mode. Fig. 1 shows both the near-field (insets) and far-field patterns of light scattering around a Silicon nanodisk, satisfying the directional conditions, either the zero-backward (R=80nm, H=50 nm, Fig. 1a) or minimum-forward (R=72nm, H=200nm, Fig. 1c) when light polarization is TE. As soon as the incident polarization is shifted to a TM mode, the spatial scattering distribution drastically changes, disappearing any directionality and tending to a dipolar behavior (Figs.1b-d).

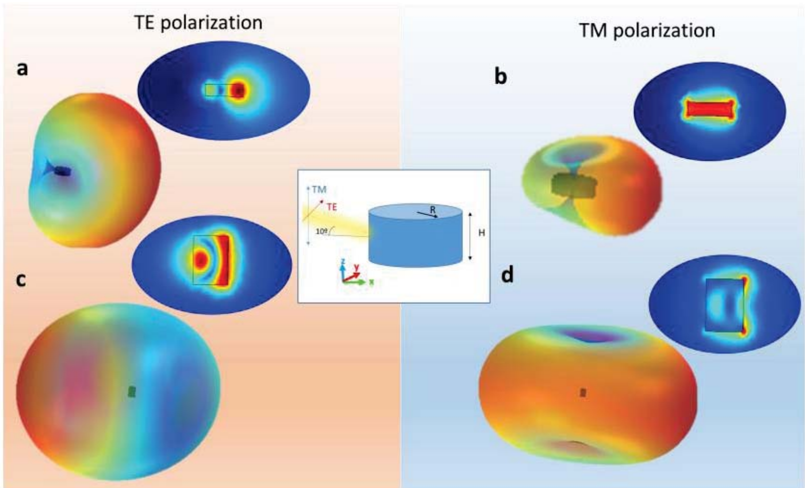

Fig. 1 Spatial distribution of light scattering around a silicon Nanoparticle satisfying either the zero-backward condition (**a**,**b**) or the minimum forward condition (**c**,**d**) when the incident light is linearly polarized with a TE mode (left panel) or a TM mode (right panel). Both the far-field and near-field regions are included. The inset shows an scheme of the geometrical conditions.

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Towards the Polarization Control of the Directional Scattering of Semiconductor Nanodisks

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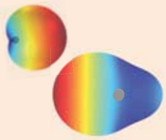
Abstract

In this work we analyze the sensitivity of the directional scattering conditions in semiconductor nanodisks with the polarization of the incident light. The possibility to reach or not this directional scattering as a function of the polarization of the incident beam could be very interesting for the design of new all-optical devices for optical communications and circuitry.

Introduction

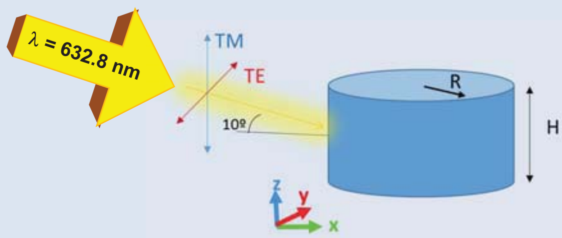
- Resonances in high-permittivity dielectric nanoparticles (NPs) can interact in such a way that a highly directional scattering can be obtained.
- This directionality arises when a dipolar character dominates and Mie coefficients satisfy the Kerker's conditions.

$a_1 = b_1$ ➡ Zero Backward Scattering (ZB)
$a_1 = -b_1$ ➡ Minimum Forward Scattering (MF)



- While in spheres, the directional conditions can be tuned by changing the ratios NP's dimensions/incident wavelength, or NP/surrounding medium refractive index, the anisotropy of cylinders offers a new degree of freedom: **the incident polarization**.

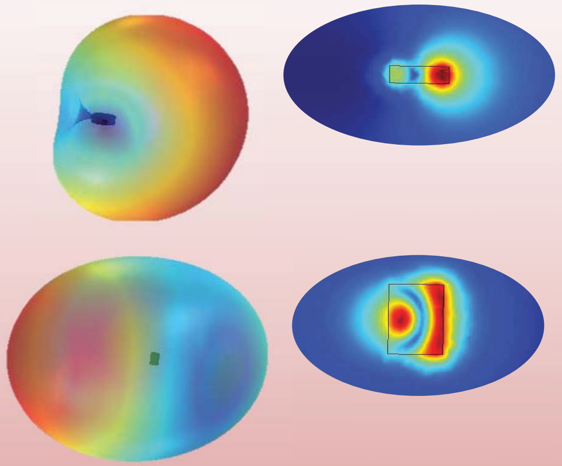
Geometry



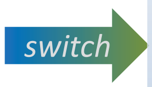
Results

- Silicon nanocylinders (from disks to pillars) will simulated using COMSOL ©.
- The dimensions, both radius (R) and height (H) will be optimized to observed directional scattering at an incident wavelength of 632.8 nm (He-Ne laser).
- The illumination beam impinges with a angle of 80º with respect to the normal direction of the cylinder to exploit the polarization anisotropy.

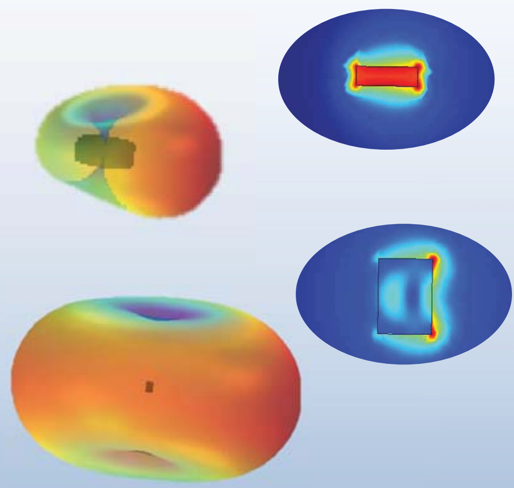
TE polarization



- **A convenient nanodisk shows a remarkable ZB scattering.**
- **An optimized nanopillar shows a clear MF scattering with the same incidence conditions.**
- **The electric field distribution in the nanoparticles shows the required profile to produce these effects.**



TM polarization



- **Both far-field and near-field profiles show a simple dipolar behavior.**
- **It appears both in nanodisk and nanopillar.**

Conclusions

- Considering Silicon nanocylinders in air, illuminated with a TE linear-polarized beam, we obtained directional scattering, either in the backward or forward directions, at 632.8 nm (He-Ne laser).
- As the incident polarization changes from TE to TM interchanged, the directional conditions are not satisfied anymore and the spatial distribution of the electric field in the surroundings of the nanodisk strongly changes, behaving like a simple dipole.
- Both the radius and the height of the disk were optimized to obtain a maximum contrast between both polarizations.

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